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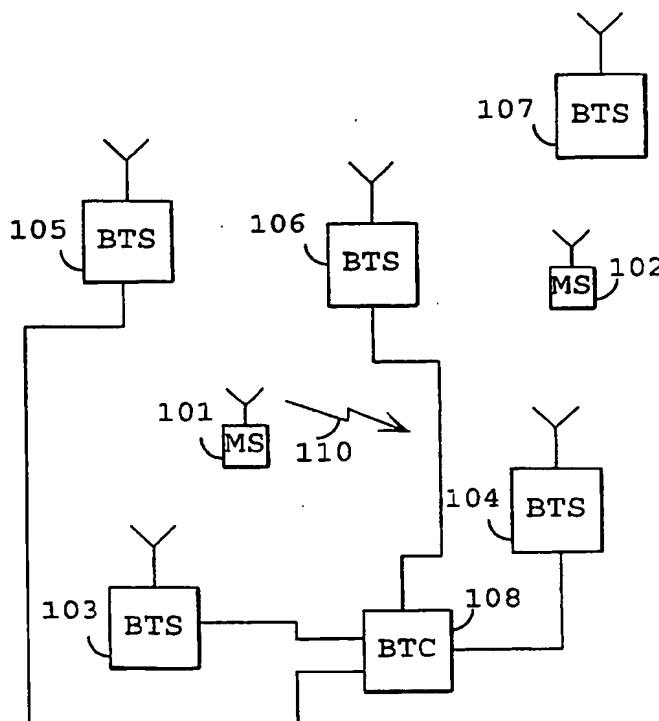
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<b>(21) International Application Number:</b> PCT/FI95/00467 <b>(22) International Filing Date:</b> 31 August 1995 (31.08.95) <b>(71) Applicant (for all designated States except US):</b> NOKIA TELECOMMUNICATIONS OY [FI/FI]; Mäkkylän puistotie 1, FIN-02600 Espoo (FI). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> KEURULAINEN, Jere [FI/FI]; Temppelikatu 1 C 22, FIN-00100 Helsinki (FI). HÄKKINEN, Hannu [FI/FI]; Vuokselantie 10 B, FIN-02140 Espoo (FI). HÄMÄLÄINEN, Seppo [FI/FI]; Lintuvaarantie 21 A 5, FIN-02600 Espoo (FI). <b>(74) Agent:</b> TEKNOPOLIS KOLSTER OY; c/o Oy Kolster Ab, Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).		<b>(81) Designated States:</b> AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>In English translation (filed in Finnish).</i>	

**(54) Title:** A HANDOVER METHOD, AND A CELLULAR RADIO SYSTEM

**(57) Abstract**

The invention relates to a handover method in a cellular radio system, and a cellular radio system. The cellular radio system comprises at least one subscriber terminal (101 and 102) and a base station (103 - 107), and in the system the subscriber terminal (101) maintains and continuously updates an active set of base stations (103 - 106), one or several base station (103 - 106) belonging to the active set having a connection or connection set-up facilities to the subscriber terminal. The subscriber terminal (101) controls the downlink transmission of one or several base stations (103 - 106) of the active set by switching the transmission of the base station on or off. This method provides a fast soft handover similar to the hard handover.



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A handover method, and a cellular radio system

5 The invention relates to a handover method in a cellular radio system comprising at least one subscriber terminal and a base station, and in which system the subscriber terminal maintains and continuously updates an active set of base stations, one or several base stations belonging to the active set having a connection or connection set-up facilities to  
10 the subscriber terminal.

The invention also relates to a cellular radio system comprising at least one subscriber terminal and a base station, in which system the subscriber terminal maintains and continuously updates an active set of base  
15 stations, one or several base stations belonging to the active set having a connection or connection set-up facilities to the subscriber terminal.

When a subscriber terminal moves from one cell to another in a cellular radio system, a handover is  
20 performed, and this handover is either in a simple case a hard handover or a more flexible soft handover. The drawback of the hard handover is that the old connection is broken before a new one is set up. The problem is more marked especially in the ping-ponging effect  
25 wherein a channel keeps changing back and forth between different channels. This can be diminished by using a handover margin. However, the best base station connection cannot be utilized in such a case due to the handover margin and the delay of the handover procedure, wherefore an unnecessarily high transmit power must be  
30 used and the disturbance power of the system thereby increases.

The prior art soft handover also employs updating margins, which are covered, however, in the  
35 reception of the subscriber terminal by signals from

base stations with better audibility. Furthermore, even these unnecessary signals increase the transmit power of the base stations and interfere with the other subscriber terminals. The prior art handover is described for example in Finnish Patent Application 952,396 (Granlund, Häkkinen, Hämäläinen): "Method for improving the reliability of handover and call establishment, and a cellular radio system", which is incorporated herein by reference.

As it is known, a pilot signal is used to identify a base station and to form an active set in the CDMA system. A pilot signal is a data-unmodulated spreading-coded signal, which is continuously transmitted by each base station to its coverage area. A terminal equipment can identify the base stations on the basis of the pilot signal, since the spreading codes of the pilot signals differ from one another.

Subscriber terminals continuously measure pilot signals. In order to reduce the measurement load of a terminal equipment in prior art systems, each terminal equipment maintains a measurement list of the base stations and the corresponding spreading codes of the pilot signals that are situated near the terminal equipment and that are possible candidates for handover or connection establishment. The base stations on the measurement list form a group of candidates, which may become members of the active set. It is possible to establish connections rapidly to the active set from the fixed network. Terminal equipments monitor with the highest priority the pilot signals of only those base stations that are on the measurement list.

When a terminal equipment moves, the measurement list must naturally be updated as the need arises. In the prior art systems updating is performed according to the measurement performed by the terminal

equipment on the strength of the pilot signal, i.e. if a pilot transmitted by a base station is received with adequate strength, it is added to the measurement list.

5 A rake receiver used in particular in the CDMA system comprises several branches, each of which may be synchronized with a different signal component. The receiver can therefore receive several signals simultaneously. On the basis of the measurements of the pilot signal, the branches of the rake receiver are also  
10 caused to receive signals that arrive along different propagation paths. The rake receiver adapts to the attenuation changes over the different connections considerably faster than the active set is updated.

In a CDMA network providing many services there  
15 occur, however, situations wherein the load of the base station in the transmission direction from the terminal equipment to the base station, i.e. in the uplink transmission direction, is considerably greater than in the opposite transmission direction. An example of this  
20 is the unidirectional data transmission from the terminal equipment to the network. The prior art arrangements for updating the measurement list do not detect and therefore change the load of the base station in this transmission direction.

25 Even though the best signal can be selected and the power of signals which have propagated along different paths can be compiled when a rake receiver is used in the subscriber terminal, the number of the rake branches is limited by the power consumption and the  
30 manufacturing costs, and therefore the rake receiver cannot utilize, however, more than a few transmissions at a time.

Neither do the known systems provide the possibility of transferring connections to other base

stations in a situation where an individual base station is overloaded.

5           The purpose of the present invention is to avoid the problems of the known arrangements and to implement a soft handover in the manner of hard handover with a very small effective handover margin, and to decrease the disturbance power of the base station when the subscriber terminal communicates with several base stations.

10           This is achieved with the method of the type described in the preamble, characterized in that the subscriber terminal controls the downlink transmission of one or several base stations of the active set in such a way that each base station switches its  
15           transmission on or off.

          The cellular radio system according to the invention is characterized in that the subscriber terminal comprises means for controlling one or several base stations of the active set in such a way that each  
20           base station switches its downlink transmission on or off.

          The invention provides considerable advantages. The number of signals transmitted by the base stations can be decreased, and the interference level caused by  
25           the base stations can thereby be reduced. This in turn increases the capacity of the system and improves the quality of the connections.

          Handover also becomes faster. The updating of the active set is slow and requires a great deal of signalling. According to the invention, a base station  
30           can be activated by means of the internal signalling of the radio interface or alternatively by means of routed signalling. A mobile station has to keep active only 1 to 3 base stations providing the best connection, and  
35           to update this group rapidly by means of the signalling

according to the invention. The result is a process, similar to a hard handover, from the base station to the terminal equipment with a very small effective handover margin.

5           The fixed network may operate in the same manner as in a conventional macro diversity system, and the arrangements according to the invention are only directed at the radio interface.

10           The invention enables the size of the active set and the selection margin to be increased without increasing the interference. This facilitates the maintenance of the best connection especially under difficult circumstances in a microcell environment.

15           The preferred embodiments of the method according to the invention are also disclosed in the appended dependent claims 2 to 11, and the preferred embodiments of the cellular radio system according to the invention are disclosed in the appended dependent claims 13 to 21.

20           The invention will be described in greater detail below with reference to the examples according to the accompanying drawings, in which

Figure 1 shows a cellular radio system,

25           Figure 2 shows the essential parts of a subscriber terminal, and

Figure 3 shows the essential parts of a base station.

30           The method according to the invention will be described in greater detail below. In the method according to the invention, the selection of the macro diversity active set is based on the comparison of pilot signals, transmitted by the base stations, in the subscriber terminal. When the power of a pilot signal of a base station received at a subscriber terminal  
35           comes close to the power of the strongest received pilot

signal within a certain margin, this base station is added to the active set of base stations maintained by the subscriber terminal. Otherwise the base station is removed from the active set when its signal deteriorates. The base stations of the active set are synchronized and receive the signal of the subscriber terminal if the signal-to-interference ratio enables it. Connections are established from the base stations through the fixed network, and through these connections the signals received by the base stations can be combined. The signal of the base stations of the active set to be transmitted to the subscriber terminal is transferred in a similar manner. The base stations of the active set have connections or at least connection set-up facilities to the subscriber terminals.

By means of measurements of signal quality, a subscriber terminal can change the transmission of the base stations. The subscriber terminal controls the downlink transmission of the base stations by switching the transmission on or off. When the base station transmission is switched off in the arrangement according to the invention, the base station transmission is completely terminated or the transmit power is decreased by a desired degree, so that the interference caused by the base station disappears. The decrease in the transmit power can be for example between 40 dB and 3 dB. Switching a base station transmission on and off is preferably performed by means of a control signal, which can be received by the base station directly from the transmission of the subscriber terminal, or the control signal can be forwarded by the fixed network. Especially the control signal that switches on the base station transmission is either common to all the base stations of the active set, or it is separate for each base station, and this control



signal is transmitted regularly, preferably at intervals of a frame. Transmitting the control signal regularly provides the advantage that the transmit power of the base stations can be adjusted at precise intervals, and when the interval between the adjustments is short, for example one frame, the adjustment is performed rapidly enough to observe even fast changes in the attenuation over the connection. All base stations receiving the control signal perform the power adjustment. The base stations which cannot receive the signal of the subscriber terminal observe the transmission error and terminate the transmission to this subscriber terminal. The transmission is terminated most preferably by decreasing the transmit power slowly within a predetermined period of time or by disconnecting the transmission after a predetermined delay. When the base station terminates the transmission after it has lost the connection, i.e. after the connection has deteriorated below a predetermined level, the advantage is that the number of the base stations communicating with the subscriber terminal can be restricted to the smallest possible. The base station starts retransmitting when it can receive the control signal of the subscriber terminal switching on the base station.

In another preferred embodiment of the invention, the subscriber terminal transmits a control signal by means of which the transmission of each base station of the active set is separately adjusted. Each of the base stations can separately receive the control signal, so that each base station adjusts its own transmit power according to what the control signal determines. The base stations that do not receive the control signal terminate the transmission to the subscriber terminal in the same manner as in the first

preferred embodiment. The advantage of transmitting the control signal separately for each base station is that the method is then more controlled and the power level of each base station can be separately adjusted to the desired value. The control signal can also be assembled of signals received by several base stations. The control signal is then assembled in some part of the network, for example in the base station controller, and the control signals are signalled separately to each base station.

Figure 1 is a diagram of a cellular radio system. The arrangement according to the invention is applicable in all interference-limited cellular radio systems, which include for example different spread spectrum systems, OFDMA systems, and in the preferred embodiment of the invention, the CDMA system. The cellular radio system comprises a number of subscriber terminals 101 and 102, and base stations 103 to 107. The subscriber terminals 101 and 102 communicate with the base stations 103 to 107 on certain traffic channels when the subscriber terminals are situated within the coverage area of the base stations. When the CDMA system is used, a traffic channel consists of a wide frequency band used by all terminal equipments 101 and 102 as they transmit to the base station 103 to 107 and also used by the base stations 103 to 107 in the downlink transmission direction. It is assumed in Figure 1 that the subscriber terminal 101 communicates with the base stations 103 and 104, but that it is in the process of shifting the connection from the base station 104 to the base station 105, since the connection with the base station 104 deteriorates and the connection with the base station 105 is improved. The terminal equipment 101 transmits a control signal 110, which connects the base stations to transmit in the downlink transmission

direction. In this example, the base stations 103, 104 and 105 form the active set of the subscriber terminal 101, since the quality of the connection to these base stations is better than the required signal noise level. Since the connection to the base station 105 is improving, which can be seen on the basis of the measurement on the pilot signal, the base station 105 then receives the control and continues the connection with the terminal equipment 101. The connection to the base station 104 deteriorates further and the base station finally loses the control signal 110. According to the arrangement of the invention, the base station then terminates the connection to the terminal equipment 101. The subscriber terminal may also transmit a control signal by means of which the downlink transmission of the base station is switched off. This control signal is preferably transmitted separately for each base station, so that not all the base stations of the active set terminate their transmission.

A base station controller 108 manages the control of the base stations 103 to 106 and assembles the signals arriving at the base stations 103 to 106 when the different parts of the signal have been received at different base stations. The base station controller 108 operates in this manner especially when, in an arrangement of the invention, the subscriber terminal 101 transmits the control signal 110 regulating the transmit power of the base stations in such a way that the different parts of the signal are received at different base stations. The base station controller 108 forwards the message of the control signal it has assembled via the fixed network 109 to the base stations 103 to 106, which operate according to the control of the control signal 110.

Figure 2 illustrates a transceiver of a subscriber terminal in the cellular radio system, the method according to the invention being applicable in such a transceiver. The receiving part of the subscriber terminal comprises a receiver unit 216 receiving a signal that is converted to an intermediate frequency, and converter means 218 in which the signal is converted to a digital form. The converted signal is supplied to detector means 220 from where the detected signal is supplied further to de-interleaving means 222 and to means 224 wherein the received signal is decoded, i.e. subjected to both channel and speech decoding.

The transmitting part of the subscriber terminal further comprises means 200 for encoding the signal to be transmitted. The encoded signal is supplied to means 202 for interleaving the encoded signal. The output signal of the interleaving means is connected to the input of the means 204, where the burst to be transmitted is formed. The resulting signal is supplied to modulation means 208, the output signal of which is supplied via a transmitter unit 210 and a duplex filter 212 to an antenna 214. The aforementioned blocks can be implemented in known manners.

The apparatus further comprises control and counting means 226, which control the operation of the other aforementioned blocks. The control means 226 may be used to adjust the transmit power of the subscriber terminal itself, i.e. the signalling and traffic channels of the subscriber terminal can be adjusted. In the arrangement according to the invention this concerns especially the control signal adjusting the transmit power of the base stations. When the power of the control signal is regulated, the number of the base stations situated within the coverage area of the subscriber terminal can be restricted. This provides the

advantage that the subscriber terminal can keep active only 1 to 3 base stations providing the best connection, and update this group rapidly by means of signalling according to the invention. This results advantageously in operation similar to a hard handover in the downlink transmission direction with a very small effective handover margin. The control means 226 receive and compare signals from different base stations. On the basis of the comparison, means 226a comprised by the control unit form a control signal or control signals adjusting the transmit power of the base stations, the signal(s) being transmitted normally via the transmitting part. Adjusting the transmission of the base stations provides the advantage that the interference level caused by the base stations can be reduced, since the total transmit power of several base stations can be optimized to suit each situation. In the arrangement according to the invention, the transmission of the base stations is adjusted in such a way that the control signal switches the base station transmission on or off. When the base station transmission is disconnected, its transmit power is entirely switched off or the transmit power has been reduced by a certain amount, for example 20 dB. The advantage provided by this procedure is a fast handover. The control means 226 can also be used to adjust the transmit power of the terminal equipment itself, the advantage being that the number of the base stations with which the terminal equipment communicates can be restricted and the number of the interference signals can be simultaneously reduced. The control means 226 and 226a of the subscriber terminal are typically realized by means of a processor, but they may also be realized with several other kinds of electronic connections, which may perform similar functions as a processor. The subscriber

terminal also comprises means 220, 226 for measuring the strength of a pilot signal it has received from a base station. If the system is a CDMA system, the detector block in the receivers, usually realized according to the rake principle, typically comprises several receiver branches at least one of which is a so-called searcher branch, which measures the strengths of the pilot signals.

Figure 3 is a diagram illustrating a transceiver of a base station. The transceiver of the base station is almost identical to the transceiver of the subscriber terminal. The transceiver of the cellular radio system according to the invention comprises means 220, 226 for estimating the attenuation over the connection between the terminal equipment and the base station by means of the received power of the pilot signal and the power used in the transmission. The transceiver of the base station further comprises means 220, 226 for estimating the signal-to-noise ratio of the uplink transmission direction on the basis of the total interference, the attenuation over the connection, and the transmit power of the terminal equipment. The base station equipment also comprises means 220, 226 for measuring the total interference of the signal it has received from the terminal equipments, and means 220 to 214, 226 for transmitting a pilot signal with known transmit power.

The greatest difference between the arrangement according to the invention and the prior art is in the control means 226. The control means 226 of the base station transceiver in the arrangement of the invention comprise means 226b for initiating a transmission to the subscriber terminal when the base station identifies the control signal of the subscriber terminal, and with the same means 226b the base station terminates the

transmission to the subscriber terminal when the base station no longer identifies the control signal transmitted by the subscriber terminal to switch on the transmission, or when the base station receives a control signal by means of which the transmission is switched off. It is possible to terminate the transmission slowly with the means 226b and to avoid an immediate disconnection by reducing the transmit power of the base station within a predetermined delay. Terminating the transmission when the control signal is no longer clear reduces the number of the base stations communicating with a particular subscriber terminal, thus decreasing interference. Avoiding an immediate connection breakdown provides the advantage that the connection between the base station and the subscriber terminal is not lost due to a temporary deterioration in the signal-to-interference ratio. The control means 226 and 226b of the base station are typically realized by means of a processor, but they may also be realized with several other kinds of electronic connections, which may perform similar functions as a processor.

Even though the invention is described above with reference to the example according to the accompanying drawings, it is clear that the invention is not restricted thereto, but it can be modified in many ways according to the inventive idea disclosed in the appended claims.

## Claims:

1. A handover method in a cellular radio system  
5 comprising at least one subscriber terminal (101 and  
102) and a base station (103 - 107), and in which system  
the subscriber terminal (101) maintains and continuously  
updates an active set (103 - 106) of base stations, one  
10 or several base stations (103 - 106) belonging to the  
active set having a connection or connection set-up  
facilities to the subscriber terminal (101),  
c h a r a c t e r i z e d in that the subscriber  
terminal (101) controls the downlink transmission of one  
15 or several base stations (103 - 106) of the active set  
in such a way that each base station (103 - 106)  
switches its transmission on or off.

2. A method according to claim 1, c h a r a c -  
t e r i z e d in that the subscriber terminal (101)  
transmits a control signal (110) on the basis of which  
20 the base station (103 - 106) switches on its downlink  
transmission.

3. A method according to claim 1, c h a r a c -  
t e r i z e d in that the subscriber terminal (101)  
transmits a control signal (110) on the basis of which  
25 the base station (103 - 106) switches off its downlink  
transmission.

4. A method according to claim 1, c h a r a c -  
t e r i z e d in that the subscriber terminal (101)  
controls its signalling and its traffic channel in such  
30 a way that one or several base stations (103 - 106) of  
the active set lose the connection to the subscriber  
terminal (101), whereupon the base station (103 - 106)  
switches off its downlink transmission.

5. A method according to claim 1, 3 or 4,  
35 c h a r a c t e r i z e d in that the base station (103



- 106) switches off the connection with the subscriber terminal (101) after a predetermined delay.

5       6. A method according to claim 1, 3 or 4 characterized in that the base station (103 - 106) switches off the connection with the subscriber terminal (101) by reducing the transmit power within a predetermined period of time.

10       7. A method according to claim 2 or 3, characterized in that the subscriber terminal (101) transmits a control signal (110) separately for each base station.

15       8. A method according to claim 2, characterized in that the subscriber terminal (101) transmits a control signal (110) that is common to all base stations (103 - 106) of the active set.

20       9. A method according to claim 2, characterized in that the subscriber terminal (101) transmits a control signal (110) at regular intervals.

25       10. A method according to claim 9, characterized in that as the transmission of the traffic channels takes place at regular intervals in the form of frames, the subscriber terminal (101) transmits the control signal (110) at intervals of a frame.

30       11. A method according to claim 2 or 3, characterized in that when the control signal (110) intended for the base station (103 - 106) is divided in fragments received by different base stations (103 - 106), the control signal (110) intended for each base station is assembled in a base station controller (108) or in some part of the network from said fragments, and the control signals formed in this

manner are signalled back to the base stations (103 - 106).

5 12. A cellular radio system comprising at least one subscriber terminal (101 and 102) and a base station (103 - 107), in which system the subscriber terminal maintains and continuously updates an active set (103 - 106) of base stations, one or several base stations belonging to the active set having a connection or connection set-up facilities to the subscriber terminal,  
10 c h a r a c t e r i z e d in that the subscriber terminal (101) comprises means (226a) for controlling one or several base stations of the active set in such a way that each base station (103 - 106) switches its downlink transmission on or off.

15 13. A cellular radio system according to claim 12, c h a r a c t e r i z e d in that the subscriber terminal (101) comprises means (226a) for forming and transmitting a control signal (110) with which the base station (103 - 106) switches on its transmission.

20 14. A cellular radio system according to claim 12, c h a r a c t e r i z e d in that the subscriber terminal (101) comprises means (226a) for forming and transmitting a control signal (110) with which the base station (103 - 106) switches off its transmission.

25 15. A cellular radio system according to claim 12, c h a r a c t e r i z e d in that the subscriber terminal (101) comprises means (226) for controlling its own signalling and traffic channels in such a way that one or several base stations (103 - 106) of the active  
30 set lose the connection to the subscriber terminal, and the base station (103 - 106) comprises means for switching off its downlink transmission when it loses the connection to the subscriber terminal.

35 16. A cellular radio system according to claim 12, 14 or 15, c h a r a c t e r i z e d in that the

17

base station (103 - 107) comprises means (226b) for switching off the transmission after a predetermined delay.

5 17. A cellular radio system according to claim 12, 14 or 15, characterized in that the base station (103 - 107) comprises means (226b) for switching off the transmission by reducing the transmit power within a predetermined period of time.

10 18. A cellular radio system according to claim 13 or 14, characterized in that the subscriber terminal (101) comprises means (226a) for transmitting a control signal (110) separately for each base station.

15 19. A cellular radio system according to claim 13 or 14, characterized in that the subscriber terminal (101) comprises means (226a) for transmitting a control signal (110) that is common to all the base stations (103 - 106) of the active set.

20 20. A cellular radio system according to claim 12, characterized in that the subscriber terminal (101) comprises means (226a) for transmitting a control signal (110) at regular intervals.

25 21. A cellular radio system according to claim 20, characterized in that as the transmission of the traffic channels takes place at regular intervals in the form of frames, the subscriber terminal (101) comprises means (226a) for transmitting a control signal (110) at intervals of a frame.

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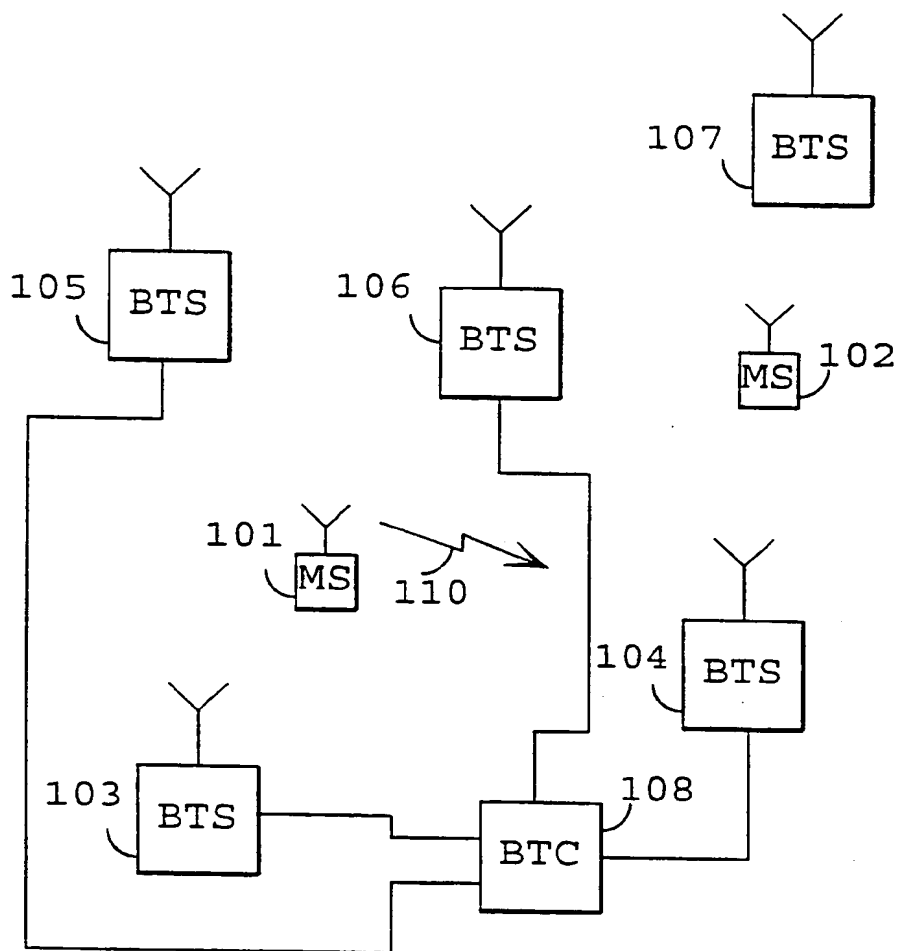


Fig. 1

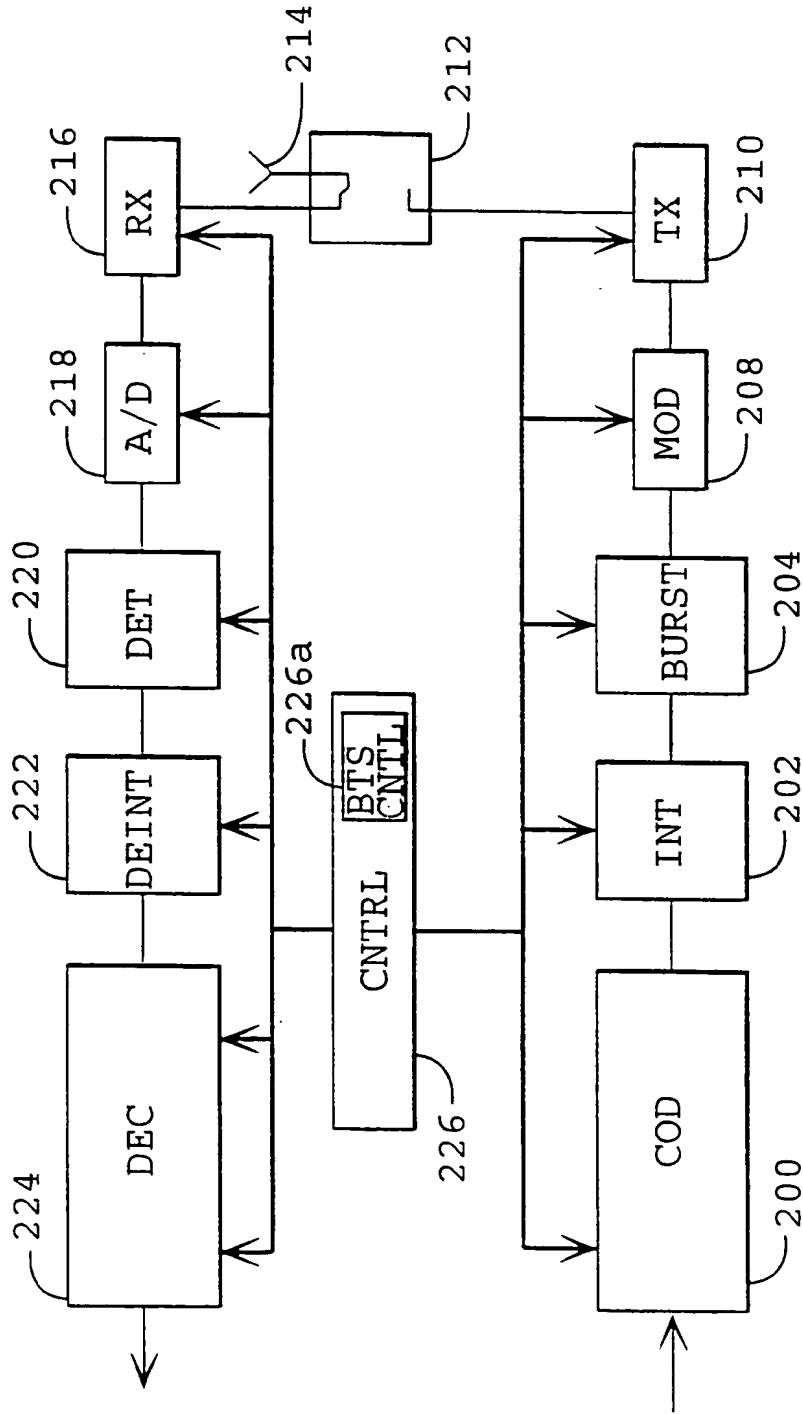


Fig. 2

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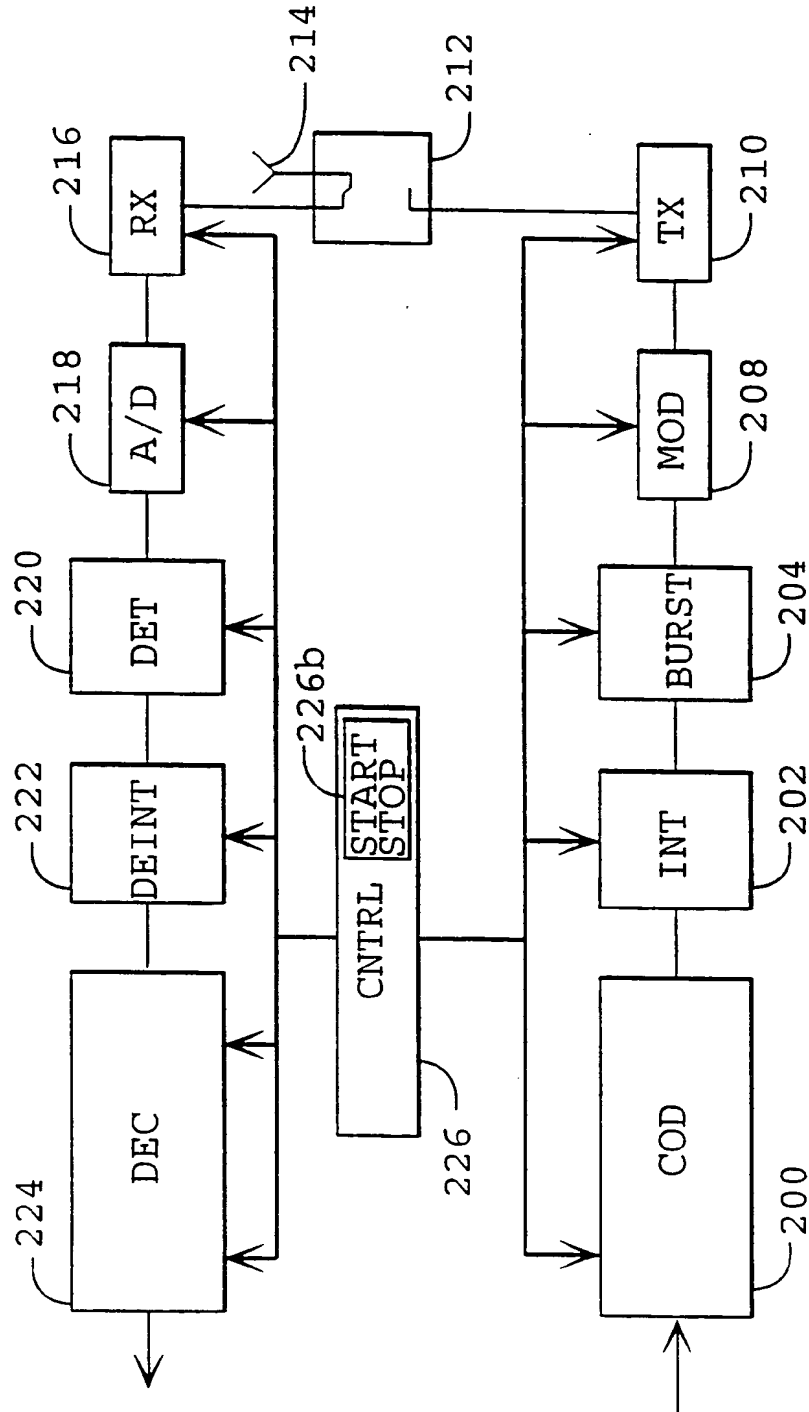


Fig. 3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 95/00467

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04Q 7/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9512297 A1 (QUALCOMM INCORPORATED), 4 May 1995 (04.05.95), page 8, line 1 - line 27, abstract	1,5,6,12
A	--	2-4,7,8, 13-19
X	US 5267261 A (BLAKENEY II ET AL), 30 November 1993 (30.11.93), column 3, line 26 - column 4, line 43; column 5, line 57 - line 63; column 8, line 47 - column 9, line 16	1,12
A	-- -----	2-8,13-19

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

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Date of the actual completion of the international search

12 June 1996

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# INTERNATIONAL SEARCH REPORT

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 9512297	04/05/95	NONE	
US-A- 5267261	30/11/93	NONE	



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